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Effects of chromium on sun flower and pearl millet in sand culture experiments

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ABSTRACT

Chromium metal is an alarmingly global issue due to industrial, automobile and anthropogenic activities. Chromium metal at higher level produce toxic effects on living organism, crop productivity and agricultural land. The data showed in pot experiment that seedling height as well as root, shoot length and number of leaves of two different food crops, *Helianthus annuus* and *Penniseum glaucum* decreased by increasing chromium (0, 25, 50, 100 and 150 ppm) level using sand culture treatment. The response of *H. annuus* and *P. glaucum* to chromium toxicity in terms of seedling size and yield production was found different. *H. annuus* showed more growth reduction by chromium treatment than *P. glaucum*. The root length of *H. annuus* was significantly decreased at chromium 100 ppm. The chromium treatments at all level produce no significant effect on leaf area and shoot growth of *H. annuus*. The seedling fresh weight of *H. annuus* was significantly reduced by 25 ppm chromium treatment. The leaves growth of *P. glaucum* was affected by different concentration of chromium. The chromium treatment at 25 ppm markedly suppressed the leaves numbers in *P. glaucum* whereas; no significant reduction in shoot length of *P. glaucum* was recorded. This study showed that 100 ppm chromium treatment significantly ($p<0.05$) decline seedling and root fresh weight of *P. glaucum*. This study suggests that *P. glaucum* showed more toxicity to chromium than *H. annuus*.

Keywords: Biomass, metal, pollution, seedling size, toxicity

1. INTRODUCTION

The industrial, anthropogenic, untreated waste water from leather industry, chemical fertilizers and vehicular activities releasing a high level of metals in air, water and soil and harming crop growth and development. Chromium is naturally occurs as chromite and known as toxic heavy metal and increasing concern in the last year (Babula et al., 2008; Saroop et al., 2022; Safwat et al., 2023). It has been documented in scientific studies about the chromium stress influences on plant growth, leaf respiration (*Salvinia minima*), alter nutrition's and water relation (Spinach), activities of enzymes, DNA damages (*Brassica napus* L), Proteomic and genetic changes in kiwi fruit pollen and developing sunflower seeds (Gupta et al., 2000; Labra et al., 2004; Gopal et al., 2009; Prado et al., 2010; Rodriguez et al., 2011; Vannini et al., 2011; Zaimoglu et al., 2011).

In a study the chromium treatment induce germination, growth, biological and roots of *Medicago truncatula* A17, for roots, stem and leave of bamboo species (Ranieri et al., 2022). In another earlier studies chromium species becomes problematic on photosynthetic (*Eudorina unicocca* and *Chlorella kessleri*), leaf chloroplast (*Pisum sativum*), physiological parameters in *Datura innoxia* and grain yield in chickpea (Juarez et al., 2008; Vernay et al., 2008; Pandey et al., 2009; Wani and Khan, 2022). Medda and Mondal, (2017) reported the severe impact of hexavalent chromium within 20 - 100 ppm on germination of seed, deformation of root of *Cicer arietinum.* Chromium is toxic element for plant due to its mobile nature and interactive effects on growth processes of barley and tobacco (Ali et al., 2011; Bukhari et al., 2015; Anjum, 2017; Ashfaque et al., 2017; Alam et al., 2021). The chromium toxicity and toxicological potential have been reported by the researchers around the world. However, there is little known about the toxicity of chromium metal on sunflower and pearl millet. The effects of chromium salt ($CrCl_3.6H_2O$) on early seedling growth performance of two important agriculture food crops of Pakistan, namely *H. annuus* and *P. glaucum* were evaluated.

2. MATERIALS AND METHODS

The coarse sand from the Karachi University Campus was collected and brought to the laboratory in polythene bags. Coarse sand was dried in air and pass from 2 mm sieve plate. The sieved soil was washed by distilled water and also with 5% HCl. The seedling growth experiment using sand culture techniques was performed in the Department of Botany, University of Karachi. The healthy seeds of sun flower and pearl millet were sown in large pots within garden soil. The irrigation was made as per requirement. Same size seedlings were shifted in pots of 7.0 X 9.8 cm diameter and depth after two weeks of their germination. The holes were made at the bottom of pot for uptake of nutrients and water.

To prevent leaching of soil, the filter paper was kept at the bottom of pot. There were five replicates with ten seedlings in each pot. All these pots were kept in clean sand in trays. 5 ml solution of chromium in different concentrations (0, 25, 50, 100, 150 ppm) having trivalent form of chromium salt ($CrCl_3.6H_2O$) were to the seedlings on weekly basis. The seedlings were irrigated daily with tap water. 5 ml Hoagland solution was also applied twice in a week. The reshuffling of Pots was done on weekly basis to avoid effects of light and shade. The experiment was completely randomized for the period of four weeks. The plants were uprooted from the pots and washed with water. All plants were dried in oven at 80 ºC for 24 hours and weighed by electrical balance to calculate dry mass. The reading for seedling, root and shoot length and leaf area was recorded. The generated data were evaluated by standard statistical technique by Analysis of Variance. The difference between means was analyzed by Duncan's Multiple Range Test at significance level <p0.05 using statistical software COSTAT version 3.

3. RESULTS

The abiotic stress conditions adversely limit plant growth and productivity. The seedlings of both species (*Helianthus annuus* and *Penniseum glaucum*) were affected by high concentrations of chromium treatment as compared to control. In the present studies the variable effects by 0, 25, 50, 100 and 150 ppm of chromium on root, shoot height, leaves number and area on *H. annuus* and *P. glaucum* was recorded (Table 1, 2). The effects of Cr on seedling fresh and dry weight of *H. annus* and *P. glaucum* were also recorded. The response of seedling development of *H. annuus* and *P. glaucum* found different to Cr treatment. The increase in chromium level slightly increases with respect to root, shoot and seedling of both crops. The root growth of *H. annuus* was distinctly affected by 100 ppm concentration of chromium (Table 1). The chromium at 25 ppm suppressed significantly the leaves number in *H. annuus* whereas reduction in the shoot growth was recorded for *H. annuus* at 100 ppm. Chromium treatment at all treatments not showed any significant impact on leaf area and shoot growth of *H. annuus*. Maximum increase in shoot length of *H. annuus* was found in control treatment. The seedling fresh and weight of *H. annuus* was reducing significantly less than 25 ppm stress condition of chromium.

Similarly, seedling growth characteristics *P. glaucum* were influenced by different concentration of chromium (Table 2). The Cr at 25 ppm differentially suppressed the leaves numbers, leaf areas and root growth performances in *P. glaucum* significantly, whereas, no significant reduction in shoot growth of *P. glaucum* was recorded at similar concentration. The decrease in plant fresh weight of *P. glaucum* was noted significantly at 100 ppm chromium treatment. The chromium stress at 100 ppm concentration produced significant effects on root and total seedling fresh weight of *P. glaucum*. The comparison of chromium treatment at all level showed nonsignificant effect on dry weight of *P. glaucum.* The results showed that *P. glaucum* showed more tolerance to chromium pollution as compared to *H. annus*. Overall, the seedlings of *H. annus* showed more reduction by chromium treatment at 150 ppm as compared to *P. glaucum*.

Table 1 Effects of chromium on different growth parameters, plant fresh and dry mass of *Helianthus annuus*

	Leaf		Root	Shoot	Seedling	Seedling	
Treatment (ppm)	Area	Numbers	Length (cm)			Fresh weight (g)	Dry weight (g)
0	2.30a	8.00c	1.526a	3.44a	4.96a	0.536c	0.338b
25	3.01a	2.80b	1.620a	3.44a	6.06a	0.152b	0.090a
50	1.25a	2.40a	1.960a	3.30a	5.26a	0.136ab	0.078a
100	2.09a	2.20a	3.600b	2.84a	6.44a	0.140ab	0.075a
150	2.14a	1.60a	2.560a	3.38a	5.94a	0.098a	0.054a
LSD P<0.05	0.092	0.167	0.054	0.172	2.90	0 .065	0.020

Numbers followed by the same letters in the same column are not significantly different, according to Duncan's multiple range tests. Symbol used: Least significance difference (LSD) values at p<0.05 level.

Table 2 Effects of chromium on growth development and biomass of *Pennisetum glaucum*

	Leaf		Root	Shoot	Seedling	Plant	
Treatment (ppm)	Area	Numbers Leaves	Length (cm)			Fresh weight (g)	Dry weight (g)
0	9.02ab	4.80b	9.30a	4.88a	14.18a	0.994a	0.502a
25	7.93a	2.40a	17.66c	3.80a	21.46a	1.780a	0.864a
50	8.31a	3.00a	13.68ab	3.10a	16.78a	1.446a	0.980a
100	10.70b	2.20a	20.32c	2.74a	21.04ab	3.024b	1.038a
150	8.85ab	2.20a	13.70ab	2.80a	16.50a	1.638a	0.722a
LSD P<0.05	1.00	0.30a	0.090	0.058	6.58	0.230	0.160

Numbers followed by the same letters in the same column are not significantly different, according to Duncan's multiple range tests.

4. DISCUSSION

Abiotic stress such as drought, climate change and high level of metals limits germination, growth and yield of food crops. Chromium is a hard metal released under combustion process, metal processing industries which ultimately contaminate air, water and soil. The inhibitory effect of chromium treatment at (25, 50, 100, and 150 ppm) was responded differently on seedlings development of *H. annuus* and *P. glaucum*. The response of both plants to chromium toxicity in terms of seedling growth and biomass were found different. The mankind using plants since old age (El-Beltagi et al., 2011). Increasing concentration of chromium salts in the substrate resulted in increased toxicity in seedlings of *H. annuus* and *P. glaucum* seedlings as compared to control. It appears that chromium treatment using different concentrations reduced the leaves number, area and shoot performances of *H. annuus*.

The inhibitory effect of chromium treatment for root, shoot and seedling growth appeared as the metal concentration increased. Chromium treatment at 25 ppm produced significant decrease in number of leaves of *H. annuus* and *P. glaucum*. This response to metal toxicity in terms of seedling growth provides an evidence of metal stress or become availability of chromium. Chemical compounds exhibit toxicity (Ren, 2003). The shoot growth of *H. annus* showed trend of decrease with the increase in dose of chromium but not at the significant level. The phytotoxicity of metals has been well documented (Taylor et al., 1991). The root elongation of *P. glaucum* at high concentration of chromium at 100 ppm was found significantly affected as compared to other treatment. The more accumulation of chromium from the substrate might be reason of reduction in root growth of *P. glaucum*. In most of the studies, similar types of toxic effects of chromium on root growth of *Sinapsis alba* seeds and decline of fresh mass of wheat (Fargašová, 1994; Singh et al., 2023).

The chromium application produced negative impact on biomass production of *H. annuus* and *P. glaucum*. The alteration in plant germination and growth development process ultimately decreases total dry matter production due to excess chromium in medium described (Shanker et al., 2005). The treatment of three different levels of chromium (20, 40 60 mg/kg) produced toxic effect on plant height of three varieties of sunflower in pot experiments (Fouzia et al., 2008). The plants acquire mineral nutrients from their native soil environments (Grattan and Grieve, 1992) and increase in nutrient concentration can lead to toxicity. The chromium toxicity has become important with the age of the organs (Delmail et al., 2011).

It is suggested that *H. annuus* and *P. glaucum* can be considered possible and useful candidates for cultivation in the chromium polluted areas. Few species have been recorded suitable for cultivation in metal contaminated areas to some extent. Some tree species likewise Salix spp. has been recommended for stabilisation in contaminated soils against metal pollution (Meers et al., 2007). Chromium treatment was found more toxic to seedling growth than seedling dry weight in *H. annuus* as compared to control. This finding appears to explain the nature of the chromium toxicity on seedling of *H. annuus*.

5. CONCLUSION

In the current study, we found that *H. annuus* exhibited a large degree of variation in metal resistance and morphological response to chromium treatment than *P. glaucum.* Resistance to chromium in *P. glaucum* can be associated with low uptake in shoot and limited accumulation in root resulting better seedling growth. Further screening of chromium tolerant crop species may prove successful plantation in metal contaminated agriculture areas where chromium pollution reduced the plant growth. The efforts have been made by researchers in recent years to build healthier and cleaner environment for all living organisms. One of the important factors for the successful plantation in polluted areas is the studies on the toxicity and tolerance of plant species to pollutants. It is suggested that detailed study is needed on similar lines to evaluate other crop species, which could tolerate metals toxicity, particularly chromium if grown on metals contaminated soil.

Informed consent

Not applicable.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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